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(54) **LENS DRIVING APPARATUS**

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G03B 3/10 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 7/09*** (2013.01); ***G03B 3/10*** (2013.01); *G03B 2205/0069* (2013.01)

(58) **Field of Classification Search**
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USPC 359/557
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,649,703 B2 1/2010 Shiraki et al.
7,932,648 B2 4/2011 Jung
8,009,371 B2 8/2011 Sue et al.
2003/0179471 A1 9/2003 Nakamura et al.
2010/0172041 A1 7/2010 Lai et al.
2011/0141564 A1 6/2011 Sata et al.
2011/0176046 A1 7/2011 Hu et al.
2014/0177056 A1 6/2014 Hayashi et al.

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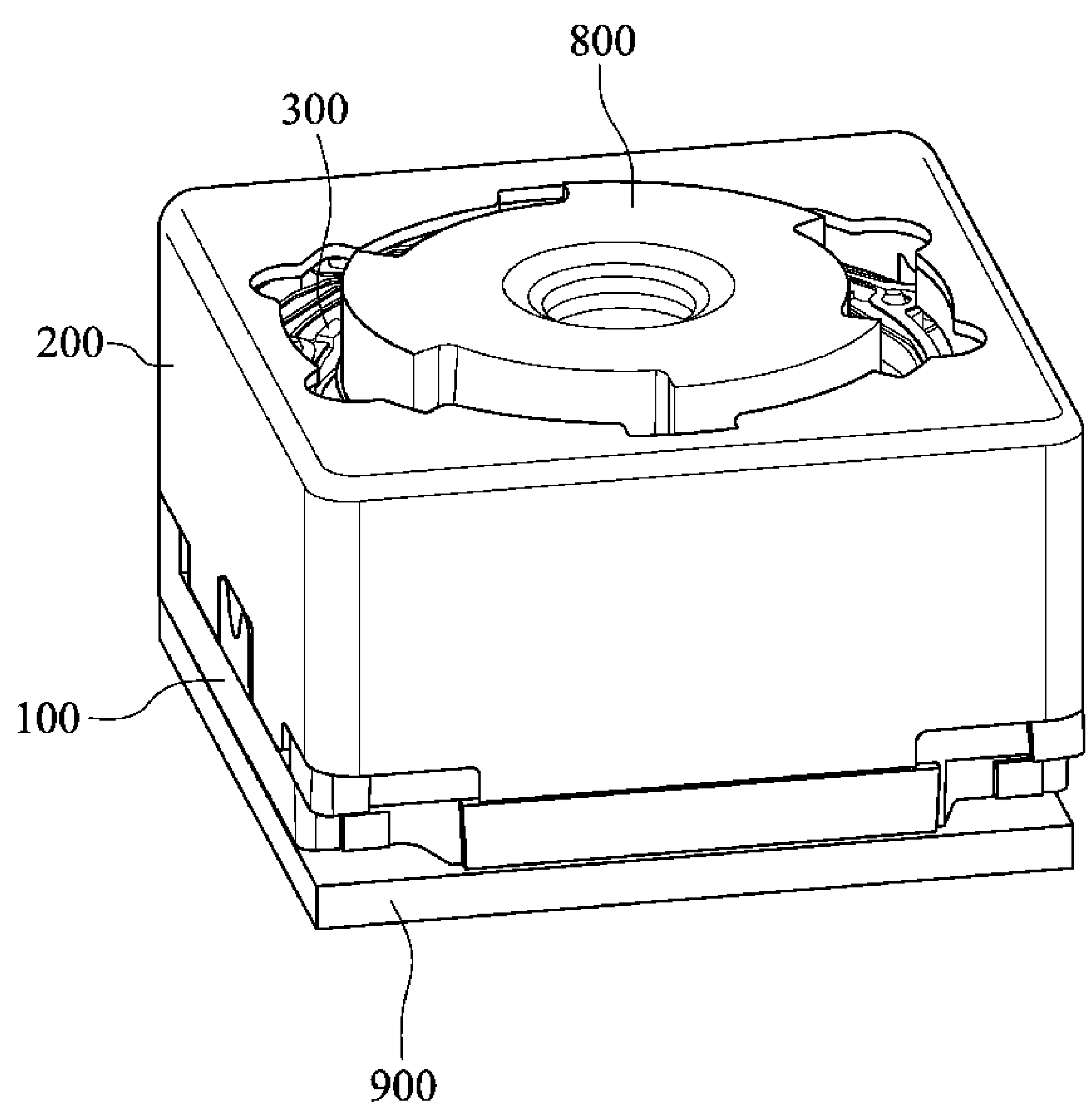
(57) **ABSTRACT**

A lens driving apparatus includes a holder, a cover, a carrier, a first magnet, a coil, a spring, two second magnets and a hall sensor. The holder includes an opening hole. The cover is made of metal material and coupled to the holder. The carrier is movably disposed in the cover, and for coupling to a lens. The first magnet is connected to an inner side of the cover. The coil is wound around an outer side of the carrier, and adjacent to the first magnet. The spring is coupled to the carrier. The second magnets are disposed on one end of the carrier which is toward the holder. The hall sensor is for detecting a magnetic field of any one of the second magnets, wherein the magnetic field is varied according to a relative displacement between the hall sensor and the second magnet which is detected.

23 Claims, 8 Drawing Sheets



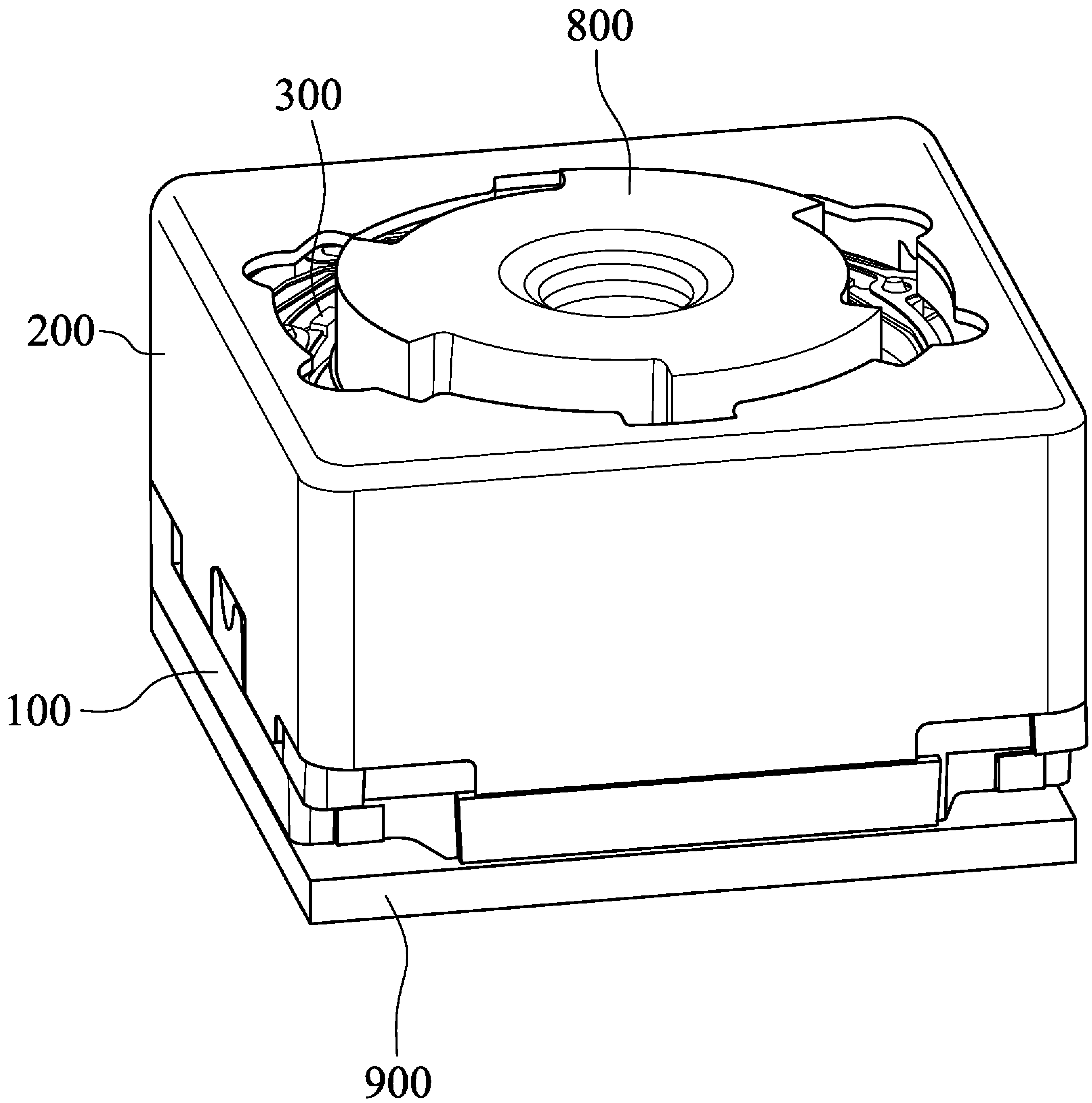


Fig. 1

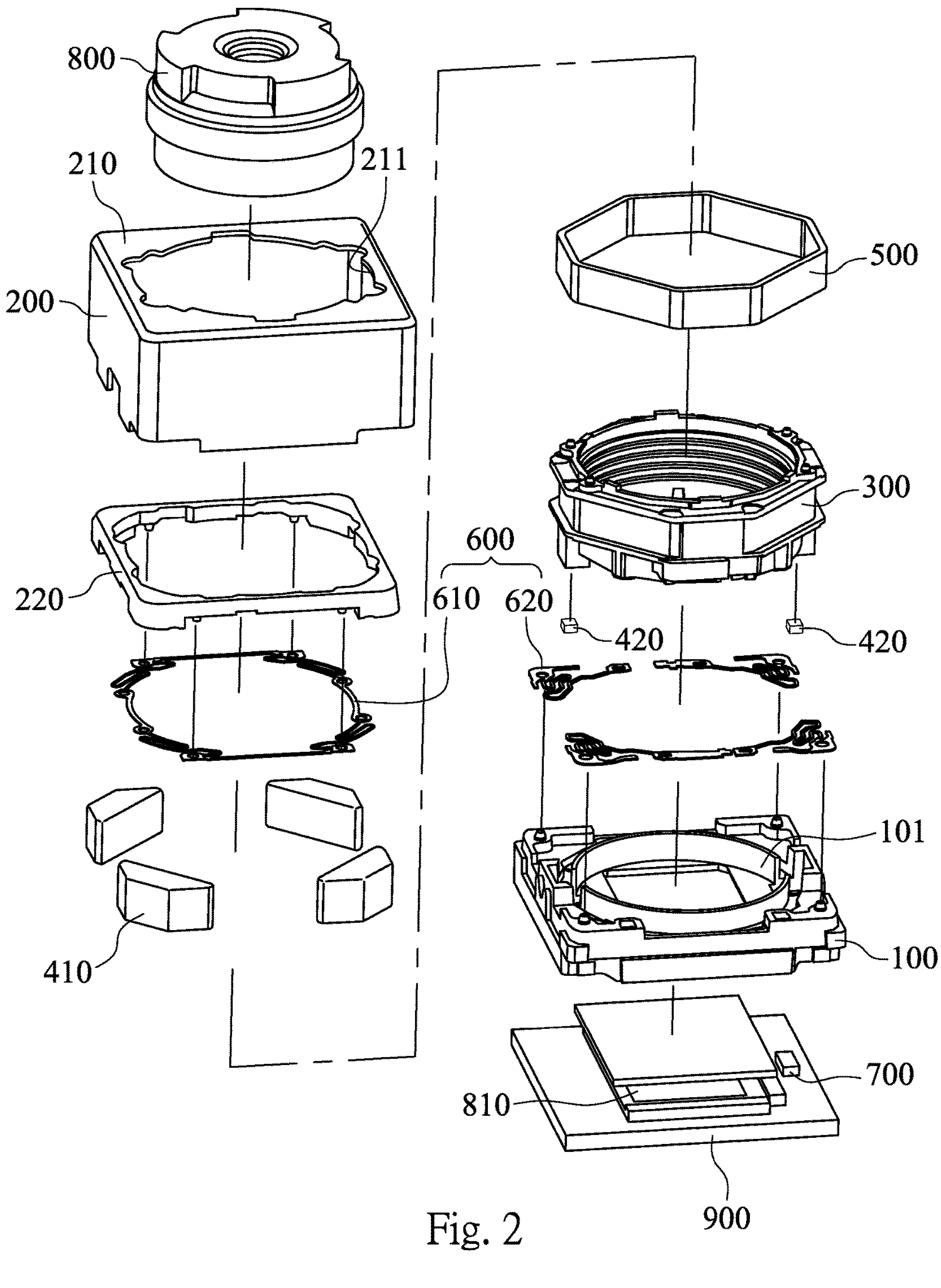

800
210
211
200
220
610
600
620
410
500
300
420
420
101
100
700
810
900

Fig. 2

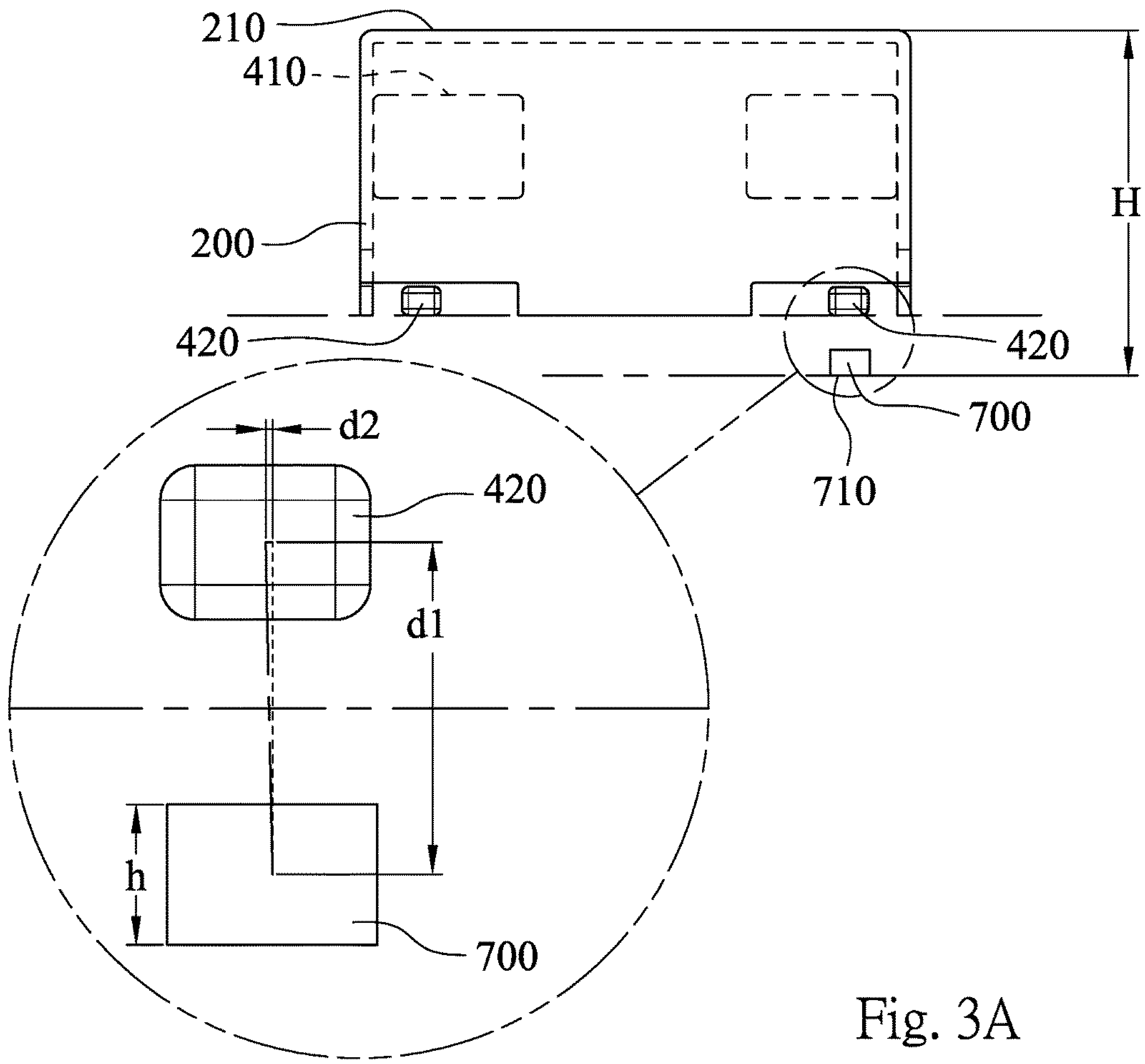

210
410
200
H
420
420
700
710
d2
420
d1
h
700

Fig. 3A

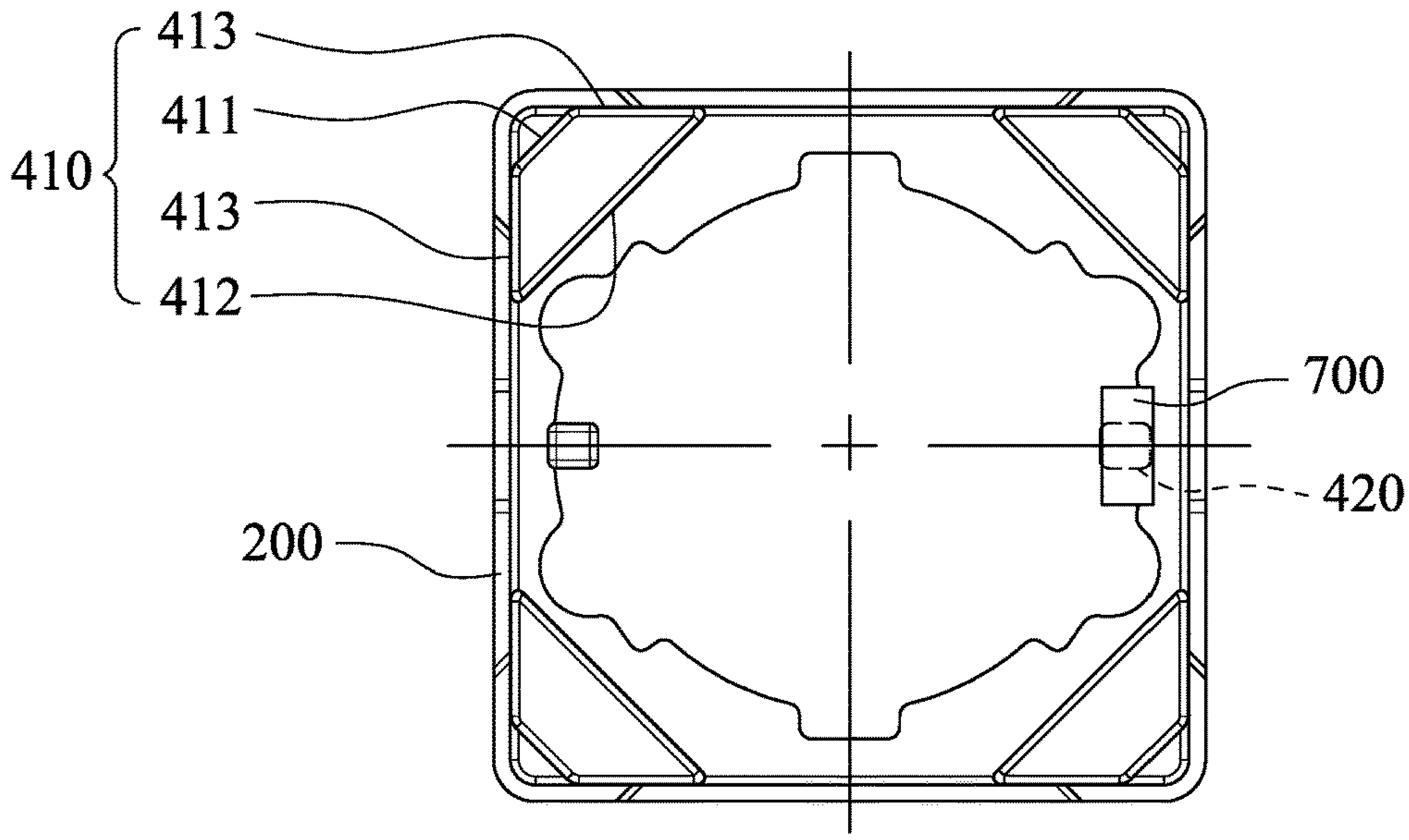

413
411
410
413
412
700
420
200

Fig. 3B

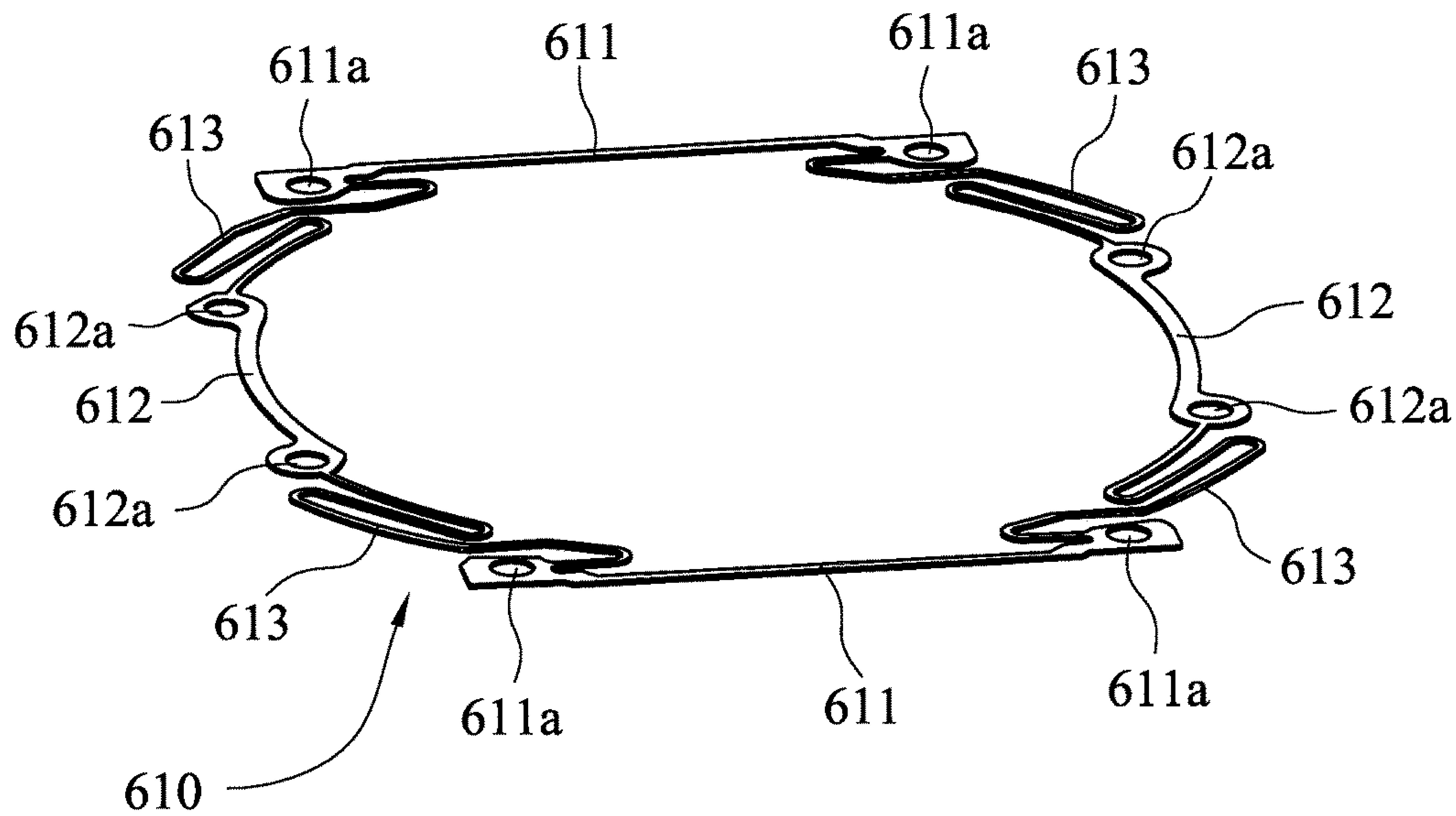

611a
611
611a
613
613
612a
612a
612
612
612a
612a
613
613
611a
611
611a
610

Fig. 4A

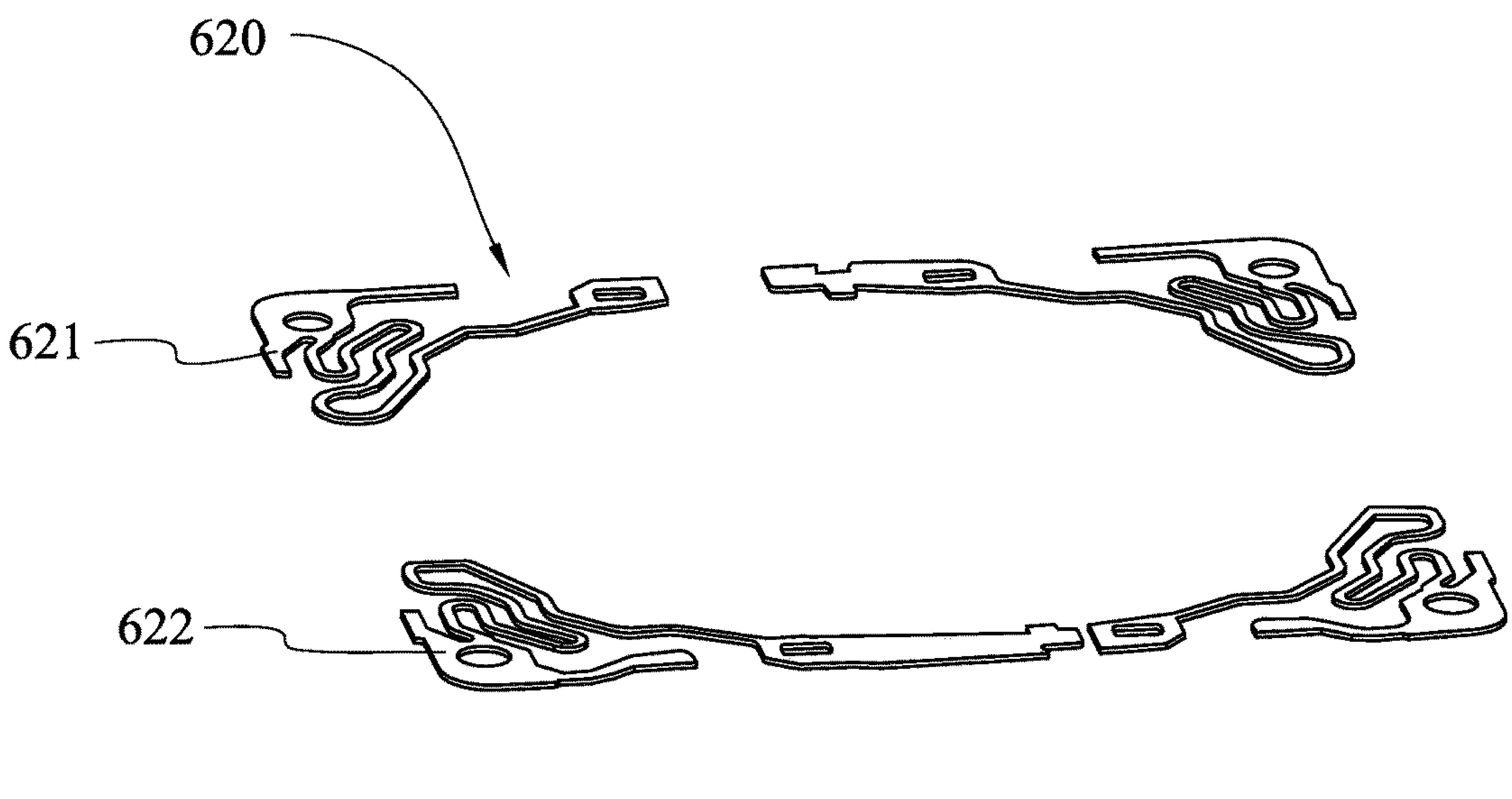

620
621
622

Fig. 4B

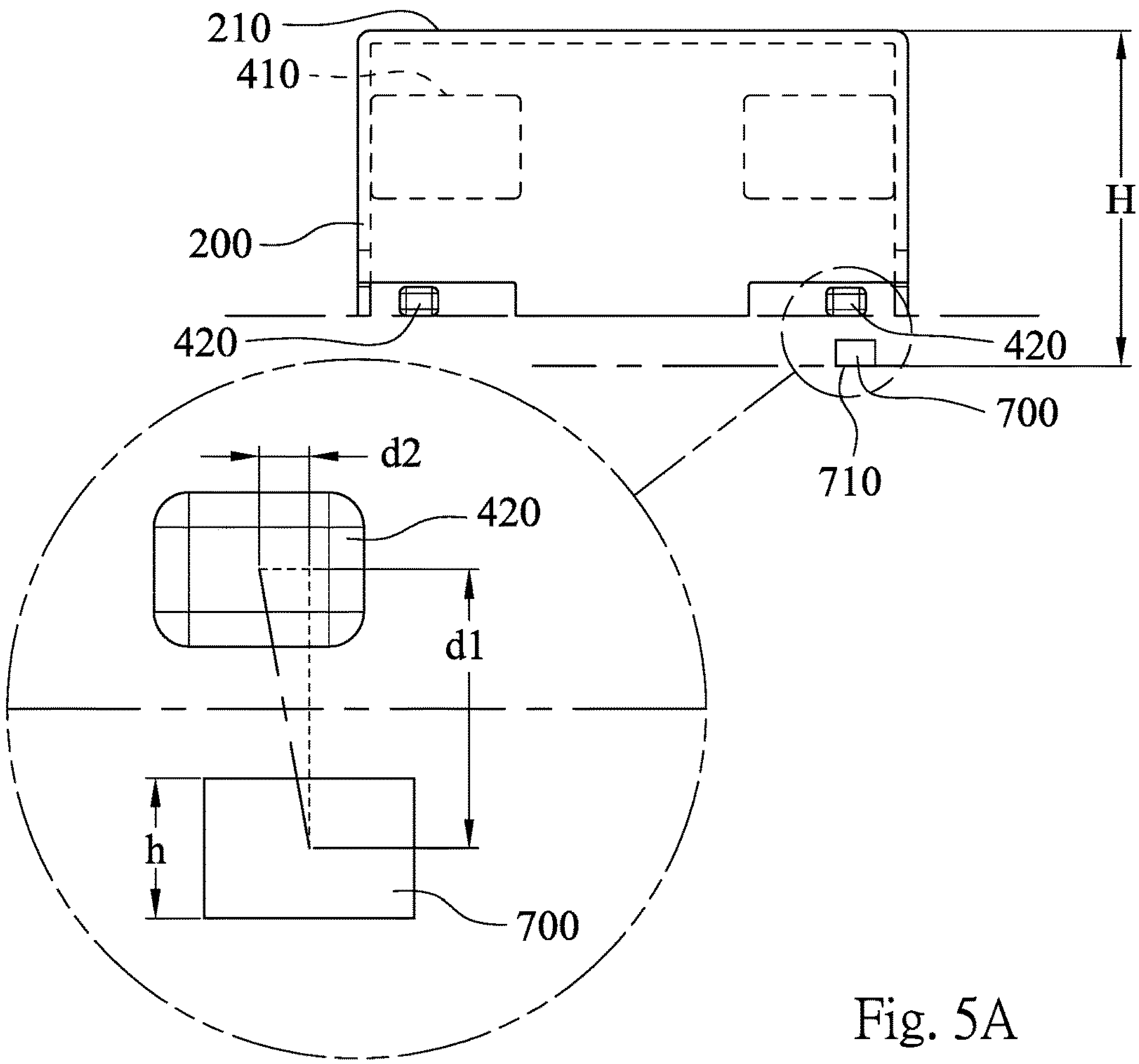

210
410
200
420
420
700
710
H
d2
420
d1
h
700

Fig. 5A

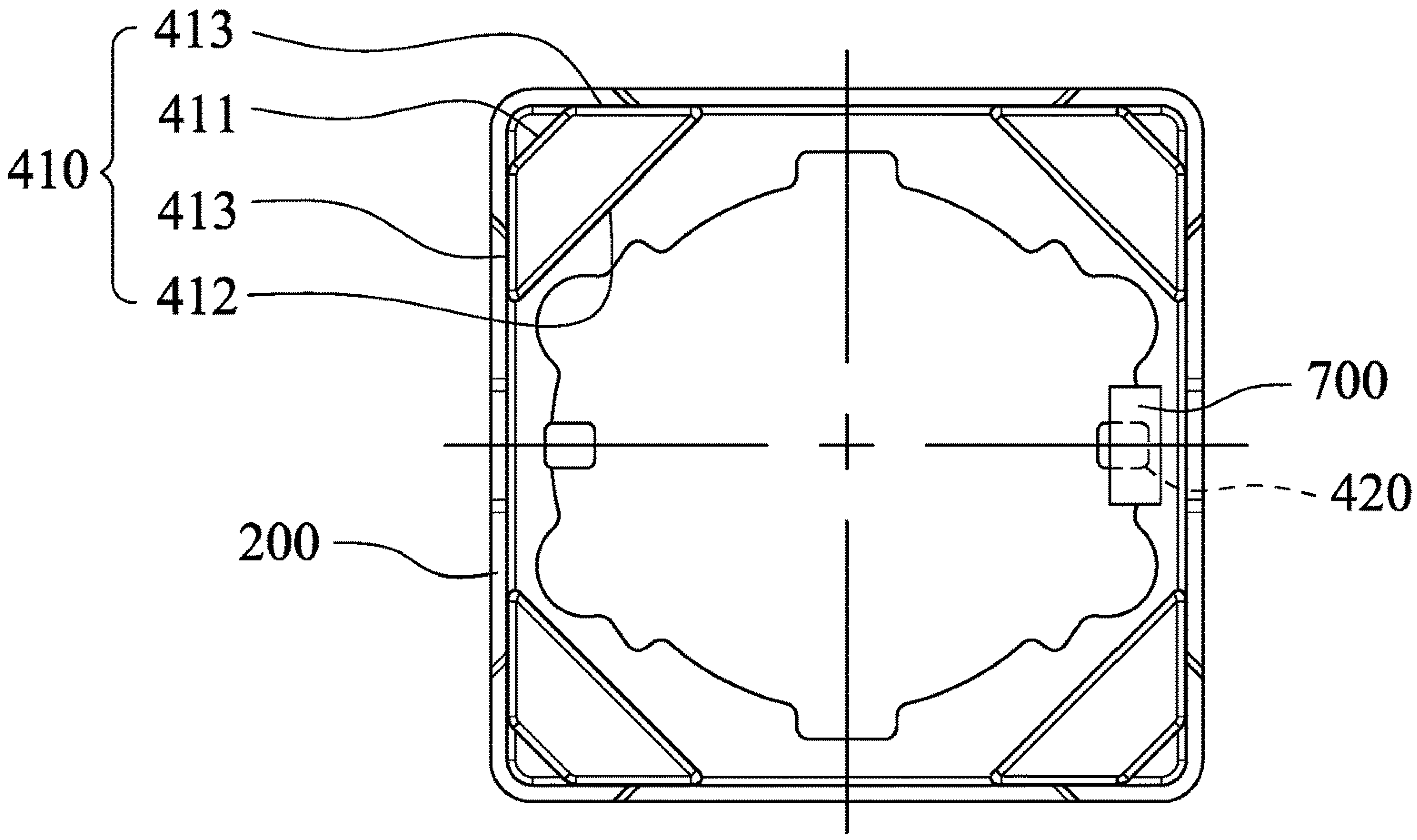

413
411
410
413
412
200
700
420

Fig. 5B

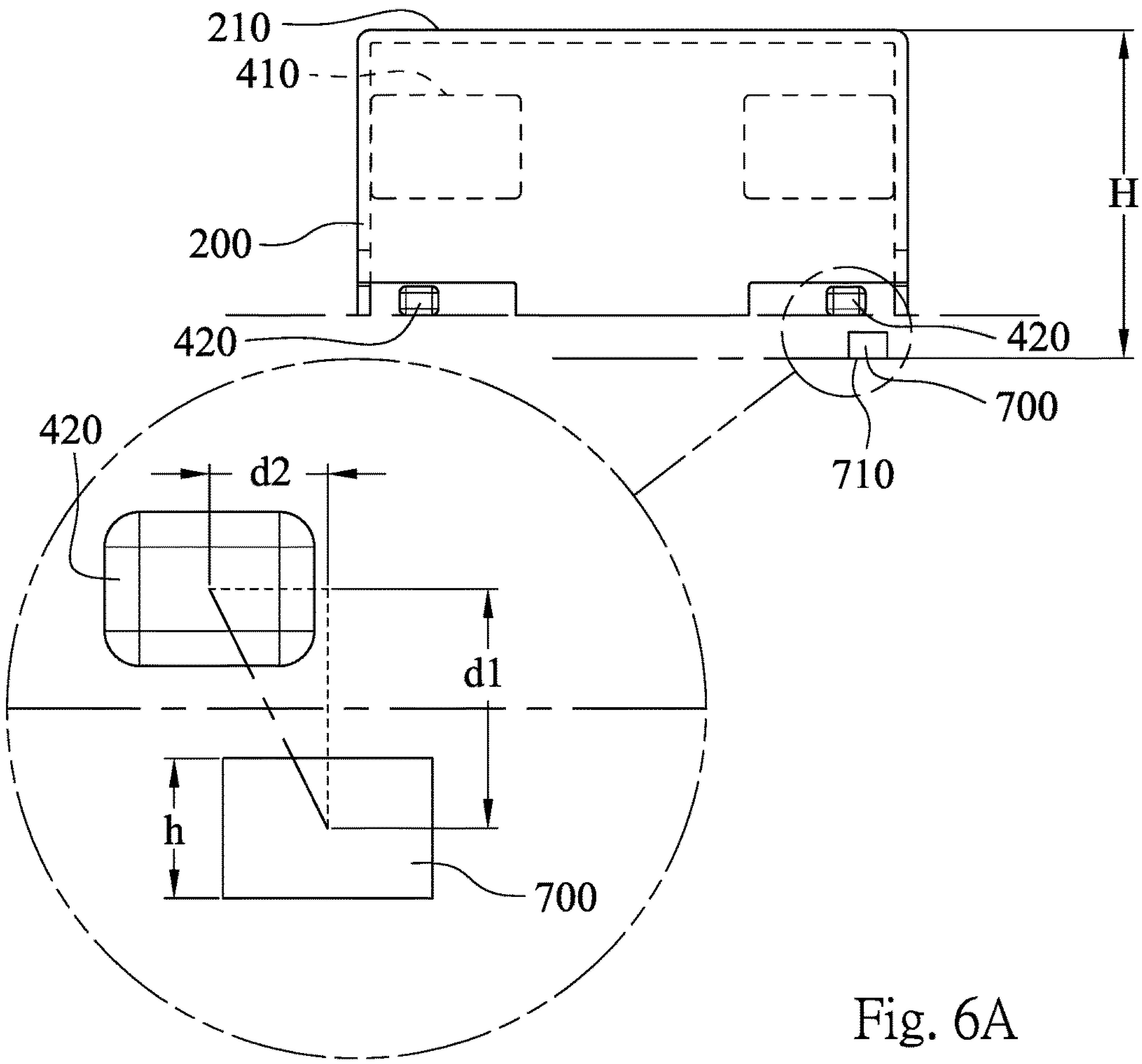

210
410
200
420
420
700
710
H
420
d2
d1
h
700

Fig. 6A

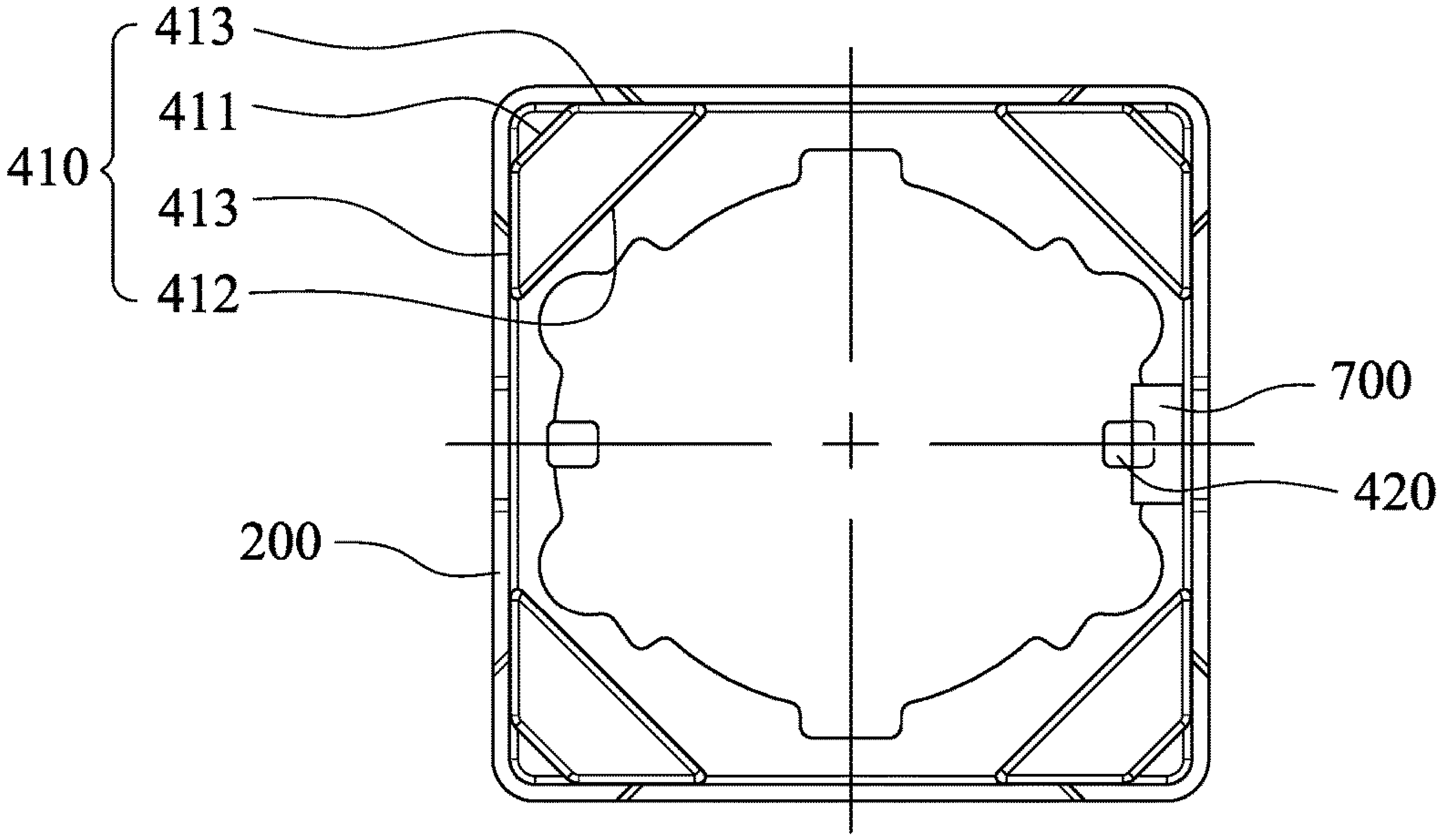

413
411
410
413
412
700
420
200

Fig. 6B

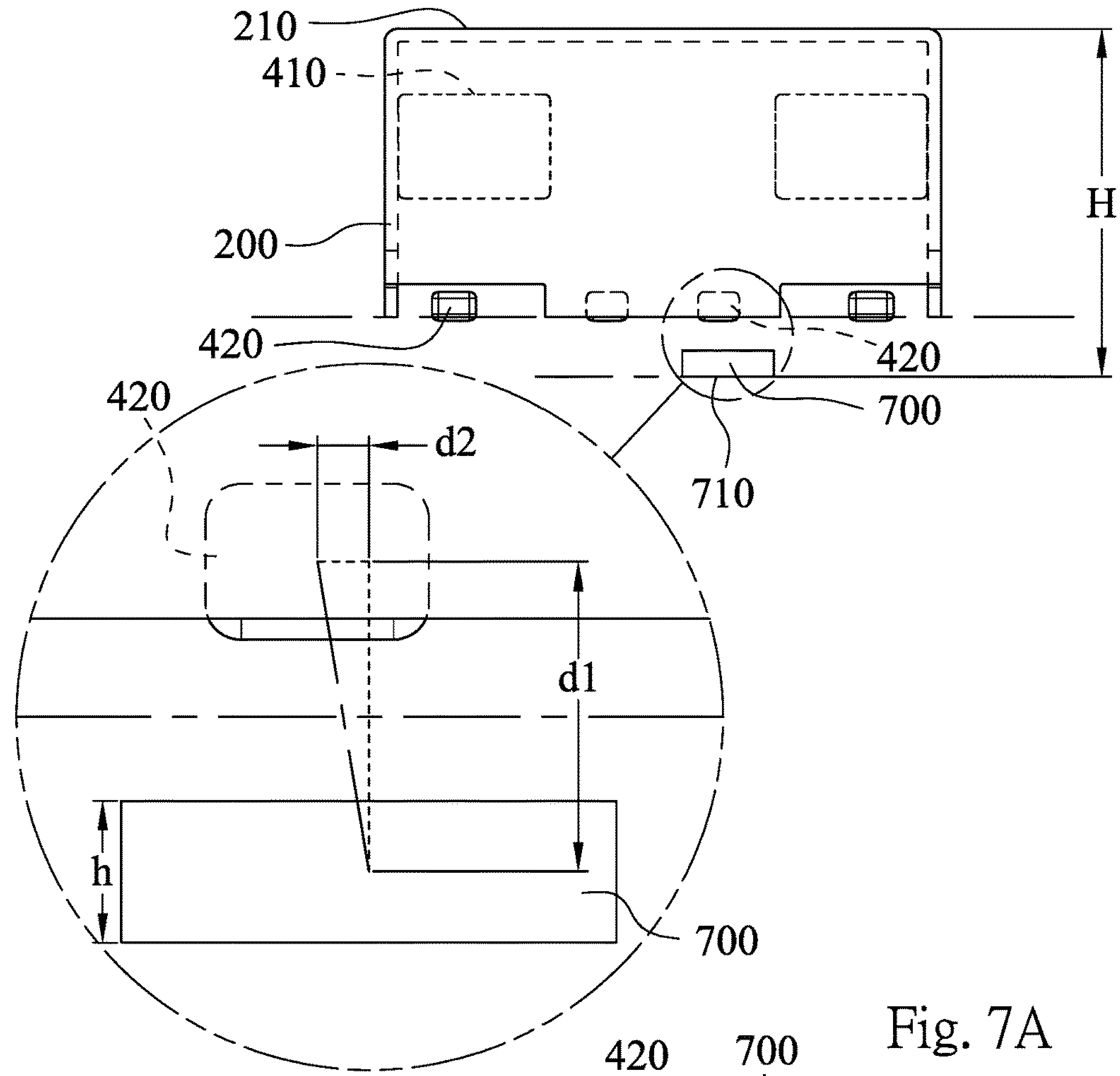

210
410
200
420
420
700
710
H
420
d2
d1
h
700

Fig. 7A

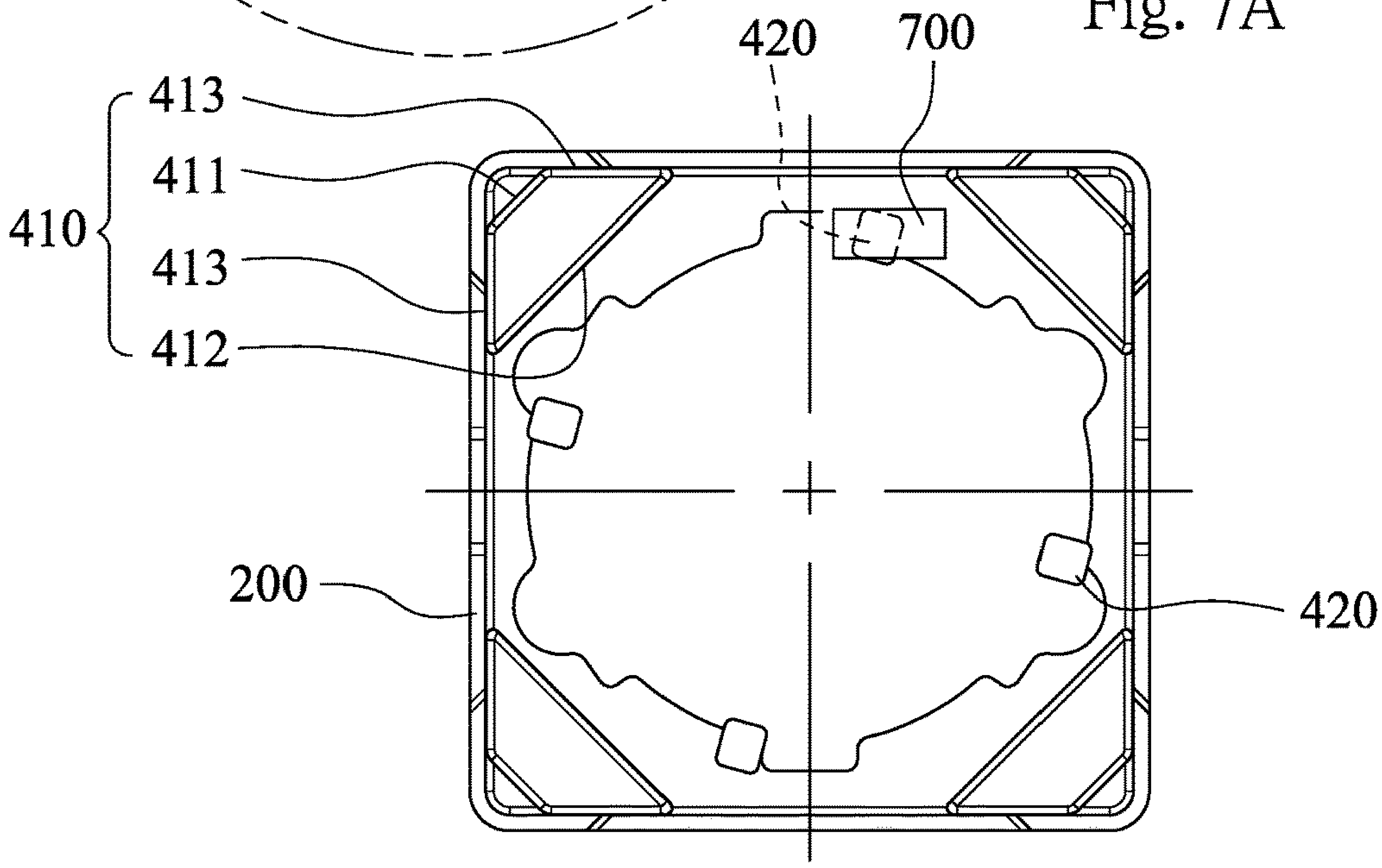

420
700
413
411
410
413
412
200
420

Fig. 7B

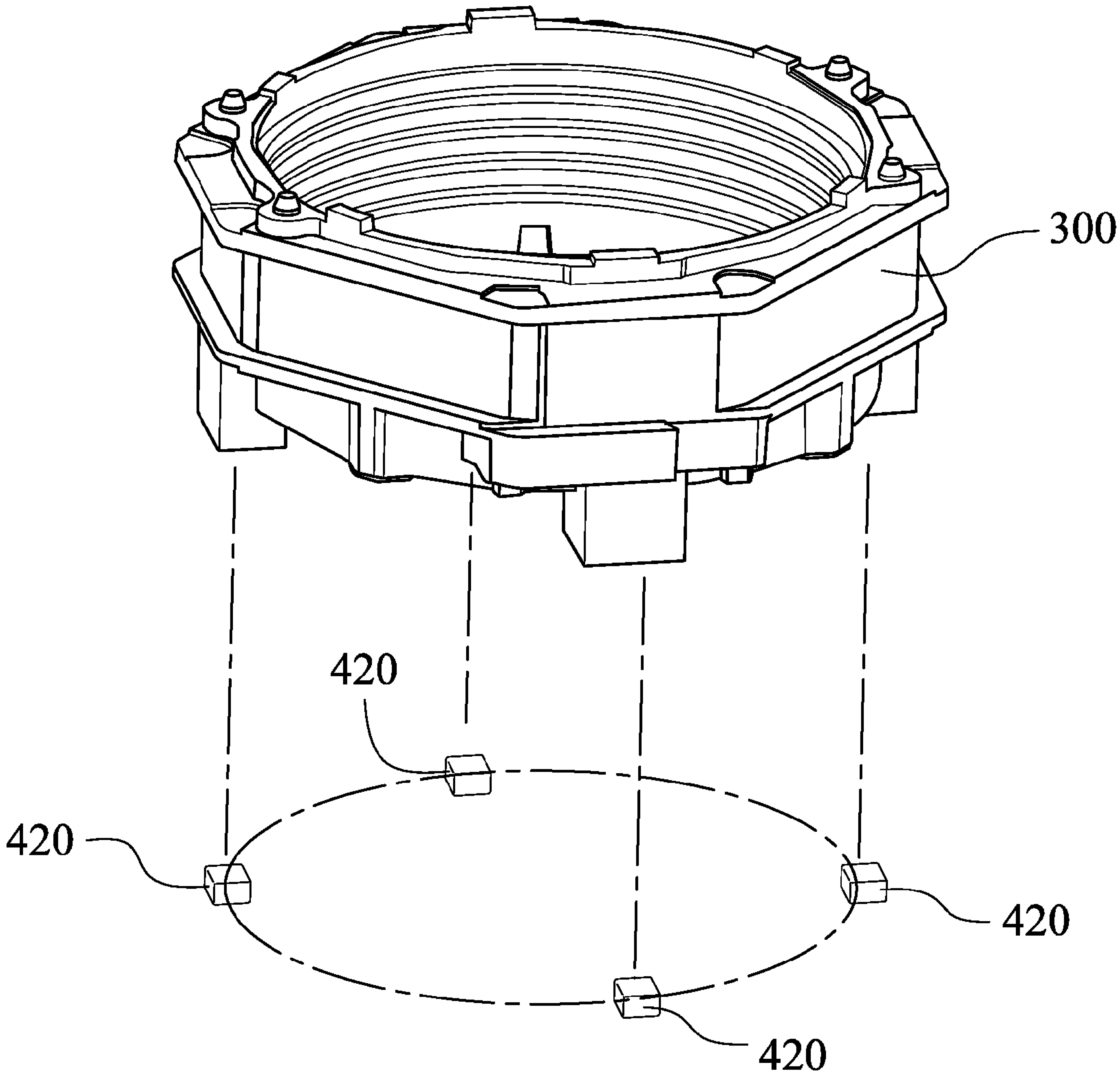


Fig. 7C

LENS DRIVING APPARATUS

RELATED APPLICATIONS

The present application is a continuation of the application Ser. No. 14/476,929, filed Sep. 4, 2014, now U.S. Pat. No. 9,778,436, the entire contents of which are hereby incorporated herein by reference, which claims priority to Taiwan Application Serial Number 103213501, filed Jul. 30, 2014, which is herein incorporated by reference.

BACKGROUND

Technical Field

The present disclosure relates to a lens driving apparatus. More particularly, the present disclosure relates to a lens driving apparatus applicable to mobile terminals.

Description of Related Art

In general, the voice-coil motor (VCM) cooperated to an open-loop controlling method is applied to the lens for providing an auto-focusing. However, the conventional VCM cannot provide feedback signal to the actuator during moving the lens, so that the present position of the lens cannot be notified immediately. Hence, the lens should be moved to the original position before focusing every time, that is, the focusing time would be lengthened and the operation would not be fluency.

SUMMARY

According to one aspect of the present disclosure, a lens driving apparatus includes a holder, a cover, a carrier, at least one first magnet, a coil, a spring, a spacer, at least two second magnets and a hall sensor. The holder includes an opening hole. The cover is made of metal material and coupled to one side of the holder. The carrier is movably disposed in the cover, and for coupling to a lens. The first magnet is connected to an inner side of the cover. The coil is wound around an outer side of the carrier, and adjacent to the first magnet. The spring is coupled to the carrier. The spacer is located between the cover and the first magnet. The second magnets are disposed on one end of the carrier which is toward the holder. The hall sensor is for detecting a magnetic field of any one of the second magnets, wherein the magnetic field is varied according to a relative displacement between the hall sensor and the second magnet which is detected.

According to another aspect of the present disclosure, a lens driving apparatus includes a holder, a cover, a carrier, at least one first magnet, a coil, a spring, at least two second magnets, a hall sensor and a circuit board. The holder includes an opening hole. The cover is made of metal material and coupled to one side of the holder. The carrier is movably disposed in the cover, and for coupling to a lens. The first magnet is connected to an inner side of the cover. The coil is wound around an outer side of the carrier, and adjacent to the first magnet. The spring is coupled to the carrier. The second magnets are disposed on one end of the carrier which is toward the holder. The hall sensor is for detecting a magnetic field of any one of the second magnets. The hall sensor and an imaging element are connected to the circuit board, and the imaging element is for receiving an imaging light of the lens. When a component parallel to an optical axis of the lens of a distance between the hall sensor

and the second magnet which is detected is d**1**, and a component orthogonal to the optical axis of the lens of the distance between the hall sensor and the second magnet which is detected is d**2**, the following condition is satisfied:

$$d1>d2.$$

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure can be more fully understood by reading the following detailed description of the embodiment, with reference made to the accompanying drawings as follows:

FIG. **1** shows an external schematic view of a lens driving apparatus according to the 1st embodiment of the present disclosure;

FIG. **2** shows an explode view of the lens driving apparatus according to the 1st embodiment of the present disclosure;

FIG. **3**A shows a schematic view of the cover, the first magnets, the second magnets and the hall sensor of the lens driving apparatus according to the 1st embodiment;

FIG. **3**B shows a bottom view of the cover, the first magnets, the second magnets and the hall sensor of the lens driving apparatus according to the 1st embodiment;

FIG. **4**A shows an enlarged view of the first spring member of the lens driving apparatus of the 1st embodiment;

FIG. **4**B shows an enlarged view of the second spring member of the lens driving apparatus according to the 1st embodiment;

FIG. **5**A shows a schematic view of the second magnets and the hall sensor of the lens driving apparatus according to the 2nd embodiment;

FIG. **5**B shows a bottom view of the second magnets and the hall sensor of the lens driving apparatus according to the 2nd embodiment;

FIG. **6**A shows a schematic view of the second magnets and the hall sensor of the lens driving apparatus according to the 3rd embodiment;

FIG. **6**B shows a bottom view of the second magnets and the hall sensor of the lens driving apparatus according to the 3rd embodiment;

FIG. **7**A shows a schematic view of the second magnets and the hall sensor of the lens driving apparatus according to the 4th embodiment;

FIG. **7**B shows a bottom view of the second magnets and the hall sensor of the lens driving apparatus according to the 4th embodiment; and

FIG. **7**C shows the carrier and the second magnets of the lens driving apparatus according to the 4th embodiment.

DETAILED DESCRIPTION

FIG. **1** shows an external schematic view of a lens driving apparatus according to the 1st embodiment of the present disclosure. FIG. **2** shows an explode view of the lens driving apparatus according to the 1st embodiment of the present disclosure. The lens driving apparatus includes a holder **100**, a cover **200**, a carrier **300**, at least one first magnet **410**, a coil **500**, a spring **600**, at least two second magnets **420**, a spacer **220** and a hall sensor **700**. In FIG. **1**, the components of the lens driving apparatus can be covered by the cover **200**, and the cover **200** is coupled to the holder **100**, so that the lens driving apparatus can be applied to the electronic product, and the components can be separated from the external environment.

In detail, the holder **100** includes an opening hole **101**, the cover **200** is made of metal material and coupled to one side of the holder **100**. In FIG. **2**, the cover **200** is cube-shaped, and a side wall of the cover **200** is composed from four wall members into closed-shape. One end of the cover **200** is an opening end, the other end of the cover **200** is an end wall **210** which is connected to the side wall and has an opening hole **211** corresponding to the opening hole **101** of the holder **100**. Therefore, the lens **800** can be movable through the opening hole **101** of the holder **100** and the opening hole **211** of the cover **200**.

The carrier **300** is movably disposed in the cover **200**, and for coupling to a lens **800**. Therefore, the lens **800** can be movable with the carrier **300**.

The first magnet **410** is connected to an inner side of the cover **200**. According to the 1st embodiment of FIG. **2**, the number of the first magnet **410** is 4. FIG. **3**A shows a schematic view of the cover **200**, the first magnets **410**, the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 1st embodiment. FIG. **3**B shows a bottom view of the cover **200**, the first magnets **410**, the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 1st embodiment. In FIGS. **3**A and **3**B, each of the first magnets **410** is a trapezoid-shaped cylinder, precisely, is an isosceles trapezoid-shaped cylinder. That is, each of the first magnets **410** has an upper surface **411**, a bottom surface **412** and two side surfaces **413**, wherein the upper surface **411** and the bottom surface **412** are unequal length but parallel to each other, and the two side surfaces **413** are equal length, and connected to the upper surface **411** and the bottom surface **412**, respectively. In FIG. **3**B, the side surfaces **413** of each of the first magnets **410** are connected to two inner surfaces which are adjacent to each other of the inner side of the cover **200**, so that the first magnets **410** are stably and equally disposed in the cover **200**.

The cover **200** is for surrounding the components of the lens driving apparatus, and each component has different shape and size. However, each of the components should be securely fixed and positioned relative to the cover **200** or the other components. Therefore, the lens driving apparatus includes the spacer **220** located between the cover **200** and the first magnets **410**. The spacer **220** can be connected to the inner side of the cover **200** for coupling or connecting to other components. It is favorable for the arrangement of the component which is covered and surrounded by the cover **200**.

The coil **500** is wound around an outer side of the carrier **300**, and adjacent to the first magnets **410**. In the 1st embodiment, the coil **500** is octagon which corresponds to the outer side of the carrier **300**, so that the coil **500** is stably connected around the carrier **300**, and four surfaces of the coil **500** are adjacent to the bottom surface **412** of the first magnets **410**, respectively. It is favorable for contributing efficiency and evenness to the interaction between the first magnets **410** and the coil **500**, so that the carrier **300** can be moved stably, and the lens **800** can also be linked up stably.

The spring **600** is coupled to the carrier **300** for providing an elastic supporting force. According to the 1st embodiment of the present disclosure, the spring **600** includes a first spring member **610** and a second spring member **620**, which are coupled to two ends of the carrier **300**, respectively. FIG. **4**A shows an enlarged view of the first spring member **610** of the lens driving apparatus of the 1st embodiment. In FIG. **4**A, the first spring member **610** includes two first fastening portions **611**, two second fastening portions **612** and four elastic portions **613**, wherein each of the first fastening portions **611** includes at least two holes **611***a* for coupling to the spacer **220**, each of the second fastening portions **612** includes at least two holes **612***a* for coupling to the carrier **300**, each of the elastic portions **613** is connected to one of the first fastening portions **611** and one of the second fastening portions **612** for providing the elastic supporting force. In detail, the first spring member **610** is about quadrangular, the two first fastening portions **611** and the two second fastening portions **612** can be regarded as four sides of the first spring member **610**, wherein each of the first fastening portions **611** is facing each other, and each of the second fastening portions **612** is facing each other. Each of the elastic portions **613** is connected to one end of one of the first fastening portions **611** and one end of one of the second fastening portions **612**. The first fastening portions **611** are connected to the spacer **220** and the second fastening portions **612** are connected to the carrier **300**, so that the first spring member **610** is positioned in the cover **200**. Moreover, in order to couple with different-shaped components, such as the carrier **300** and the spacer **220**, etc., the first spring member **610** can include a first fastening portion **611**, a second fastening portion **612** and two elastic portions **613**, and each of the elastic portions **613** is connected to one end of the first fastening portion **611** and one end of the second fastening portion **612**, and will not draw and describe herein.

FIG. **4**B shows an enlarged view of the second spring member **620** of the lens driving apparatus according to the 1st embodiment. The second spring member **620** includes a first portion **621** and a second portion **622**, wherein the first portion **621** and the second portion **622** are separated from each other, coupled to the end of the carrier **300** which is toward the holder **100** and located on a same horizontal plane.

The second magnets **420** are disposed on the end of the carrier **300** which is toward the holder **100**, and are movable simultaneously with the carrier **300**, wherein a magnetic polarization direction of each of the second magnets **420** is parallel to an optical axis of the lens **800**, and is orthogonal to a magnetic polarization direction of the first magnet **410**. The magnetic field of the first magnets **410** and the magnetic field of the second magnets **420** are not interacting with each other. The hall sensor **700** is for detecting a magnetic field of any one of the second magnets **420**, wherein the magnetic field is varied according to a relative displacement between the hall sensor **700** and the second magnet **420** which is detected. Therefore, the voltage signal as a feedback can be provided, and the lens **800** can be linked up with the carrier **300** to a predetermined position. The carrier **300** has no need to move back to the original position, and then moves to the predetermined position. In the 1st embodiment, the number of the second magnets **420** is two, and the two second magnets **420** are symmetrically disposed on the end of the carrier **300** about the optical axis of the lens **800**, but are not limited thereto.

In FIG. **3**A, when a thickness parallel to an optical axis of the lens **800** of the hall sensor **700** is h, the following condition is satisfied: $h<1.0$ mm. Therefore, the mechanical complexity can be reduced, and the assembling convenience can be increased. Preferably, the following condition is satisfied:

$$h<0.6 \text{ mm}.$$

In the 1st embodiment of the present disclosure, the lens driving apparatus can further include a circuit board **900**, which is embedded into the other side of the holder **100**. The hall sensor **700** and an imaging element **810** are connected to the circuit board **900**, and the imaging element **810** is for receiving an imaging light of the lens **800**, the imaging element **810** has 8 million pixels or above. In detail, the different voltage signal represented as the present position on the optical axis of the lens can be output due to the relative displacement between the hall sensor **700** and the second magnet **420**, and the distance between the present position and the predetermined position for focusing can be provided after the circuit board **900** receives the voltage signal, then the outputting current can be provided to the coil **500** for moving the carrier **300** and the lens **800** to the predetermined position for focusing.

In FIG. **3**A, when a vertical distance between an outermost side of the end wall **210** of the cover **200** and a side wall **710** of the hall sensor **700** which is connected to the circuit board **900** is H, and the following condition is satisfied: 3.4 mm<H<5.8 mm. Therefore, the sensitivity for detecting the magnetic field can be maintained, and the focusing time can be shortened.

The movement of the lens **800** which is linked up with the carrier **300** is adjusted corresponding to the current due to the variation of the magnetic field according to a relative displacement between the hall sensor **700** and the second magnet **420** which is detected. Therefore, the detection of the magnetic field depends on the relative position between the hall sensor **700** and the second magnets **420**. In FIG. **3**A, when a component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected is d**1**, and a component orthogonal to the optical axis of the lens **800** of the distance between the hall sensor **700** and the second magnet **420** which is detected is d**2**, the following condition is satisfied: d**1**>d**2**. Therefore, the compact size of the lens driving apparatus can be maintained.

Furthermore, when the component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected is d**1**, the following condition is satisfied: d**1**<1.4 mm. Preferably, the following condition is satisfied: d**1**<1.15 mm.

In the 1st embodiment of the present disclosure, the number of the second magnets **420**, the vertical distance between an outermost side of the end wall **210** of the cover **200** and a side wall **710** of the hall sensor **700** which is connected to the circuit board **900** (H), the thickness parallel to an optical axis of the lens **800** of the hall sensor **700** (*h*), the component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected (d**1**), and the pixel of the imaging element **810** are listed in the following Table 1.

TABLE 1

1st Embodiment				
the number of the second magnets	H(mm)	h(mm)	d1(mm)	the pixel of the imaging element
2	4.885	0.55	1.08	8 million

FIG. **5**A shows a schematic view of the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 2nd embodiment. FIG. **5**B shows a bottom view of the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 2nd embodiment. In FIGS. **5**A and **5**B, when a component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected is d**1**, and a component orthogonal to the optical axis of the lens **800** of the distance between the hall sensor **700** and the second magnet **420** which is detected is d**2**, wherein the component orthogonal to the optical axis of the lens **800** of the distance between the hall sensor **700** and the second magnet **420** which is detected (d**2**) is increased, however, the following condition is also satisfied: d**1**>d**2**.

In the 2nd embodiment of the present disclosure, the number of the second magnets **420**, the vertical distance between an outermost side of the end wall **210** of the cover **200** and a side wall **710** of the hall sensor **700** which is connected to the circuit board **900** (H), the thickness parallel to an optical axis of the lens **800** of the hall sensor **700** (*h*), the component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected (d**1**), and the pixel of the imaging element **810** are listed in the following Table 2.

TABLE 2

2nd Embodiment				
the number of the second magnets	H(mm)	h(mm)	d1(mm)	the pixel of the imaging element
2	4.300	0.32	0.82	16 million

FIG. **6**A shows a schematic view of the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 3rd embodiment. FIG. **6**B shows a bottom view of the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 3rd embodiment. In FIGS. **6**A and **6**B, when a component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected is d**1**, and a component orthogonal to the optical axis of the lens **800** of the distance between the hall sensor **700** and the second magnet **420** which is detected is d**2**, wherein the component orthogonal to the optical axis of the lens **800** of the distance between the hall sensor **700** and the second magnet **420** which is detected (d**2**) is further increased, however, the following condition is also satisfied: d**1**>d**2**.

In the 3rd embodiment of the present disclosure, the number of the second magnets **420**, the vertical distance between an outermost side of the end wall **210** of the cover **200** and a side wall **710** of the hall sensor **700** which is connected to the circuit board **900** (H), the thickness parallel to an optical axis of the lens **800** of the hall sensor **700** (*h*), the component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected (d**1**), and the pixel of the imaging element **810** are listed in the following Table 3.

TABLE 3

3rd Embodiment				
the number of the second magnets	H(mm)	h(mm)	d1(mm)	the pixel of the imaging element
2	4.370	0.65	0.64	13 million

FIG. **7**A shows a schematic view of the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 4th embodiment. FIG. **7**B shows a bottom view of the second magnets **420** and the hall sensor **700** of the lens driving apparatus according to the 4th embodiment. In FIGS. **7**A and **7**B, when a component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected is d**1**, and a component orthogonal to the optical axis of the lens **800** of the distance between the hall sensor **700** and the second magnet **420** which is detected is d**2**, the following condition is satisfied: d**1**>d**2**.

FIG. **7**C shows the carrier **300** and the second magnets **420** of the lens driving apparatus according to the 4th embodiment. In FIG. **7**C, the number of the second magnets **420** is four, and every two second magnets **420** which are adjacent to each other are equidistantly disposed on the end of the carrier **300** in a circumferential direction. Furthermore, the number of the second magnets **420** can be two to six, and even number is better, but is not limited thereto. Therefore, the balance of the lens driving apparatus can be enhanced.

In the 4th embodiment of the present disclosure, the number of the second magnets **420**, the vertical distance between an outermost side of the end wall **210** of the cover **200** and a side wall **710** of the hall sensor **700** which is connected to the circuit board **900** (H), the thickness parallel to an optical axis of the lens **800** of the hall sensor **700** (*h*), the component parallel to an optical axis of the lens **800** of a distance between the center of the hall sensor **700** and the second magnet **420** which is detected (d**1**), and the pixel of the imaging element **810** are listed in the following Table 4.

TABLE 4

4th Embodiment				
the number of the second magnets	H(mm)	h(mm)	d1(mm)	the pixel of the imaging element
4	5.230	0.45	0.98	20 million

Therefore, the movement of the lens **800** which is linked up with the carrier **300** is adjusted corresponding to the current due to the variation of the magnetic field according to a relative displacement between the hall sensor **700** and the second magnet **420** which is detected. Hence, the focusing time can be saved.

Although the present disclosure has been described in considerable detail with reference to certain embodiments thereof, other embodiments are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the embodiments contained herein.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present disclosure without departing from the scope or spirit of the present disclosure. In view of the foregoing, it is intended that the present disclosure cover modifications and variations of this disclosure provided they fall within the scope of the following claims.

What is claimed is:

1. A lens driving apparatus, comprising:
- a holder, comprising an opening hole;
- a cover made of metal material and coupled to one side of the holder;
- a carrier movably disposed in the cover, and for coupling to a lens;
- at least one first magnet connected to an inner side of the cover;
- a coil wound around an outer side of the carrier, and adjacent to the first magnet;
- a spring coupled to the carrier;
- at least one second magnet disposed on one end of the carrier which is toward the holder; and
- a hall sensor for detecting a magnetic field of the at least one second magnet, wherein the magnetic field is varied according to a relative displacement between the hall sensor and the second magnet which is detected;
- wherein a magnetic polarization direction of the at least one second magnet is parallel to an optical axis of the lens, and is orthogonal to a magnetic polarization direction of the first magnet;
- wherein the first magnet is an isosceles trapezoid-shaped cylinder, a bottom surface of the first magnet is adjacent to the coil, and two side surfaces of the first magnet are fixedly connected to the inner side of the cover;
- wherein a component parallel to the optical axis of the lens of a distance between the hall sensor and the second magnet which is detected by the Hall sensor is d**1**, and the following condition is satisfied:

$$d1<1.4 \text{ mm}.$$

2. The lens driving apparatus of claim **1**, wherein a number of the second magnet is two, and the two second magnets are symmetrically disposed on the end of the carrier about the optical axis of the lens.

3. The lens driving apparatus of claim **1**, wherein a number of the second magnet is two to six, and every two second magnets which are adjacent to each other are equidistantly disposed on the end of the carrier in a circumferential direction.

4. The lens driving apparatus of claim **3**, further comprising:
- a circuit board, embedded into the other side of the holder, wherein the hall sensor and an imaging element are connected to the circuit board, and the imaging element is for receiving an imaging light of the lens.

5. The lens driving apparatus of claim **4**, wherein one end of the cover is an end wall which is connected to the side wall and has an opening hole, a vertical distance between an outermost side of the end wall of the cover and a side wall of the hall sensor which is connected to the circuit board is H, and the following condition is satisfied:

$$3.4 \text{ mm}<H<5.8 \text{ mm}.$$

6. The lens driving apparatus of claim **1**, wherein the spring comprises:
- a first spring member coupled to the other end of the carrier; and
- a second spring member coupled to the end of the carrier which is toward the holder.

7. The lens driving apparatus of claim **6**, wherein the second spring member comprises:
- a first portion; and
- a second portion, wherein the first portion and the second portion are separated from each other and located on a same horizontal plane.

8. The lens driving apparatus of claim **7**, wherein a thickness parallel to the optical axis of the lens of the hall sensor is h, and the following condition is satisfied:

$$h<1.0 \text{ mm}.$$

9. A lens driving apparatus, comprising:
- a holder, comprising an opening hole;
- a cover made of metal material and coupled to one side of the holder;
- a carrier movably disposed in the cover, and for coupling to a lens;
- at least one first magnet connected to an inner side of the cover;
- a coil wound around an outer side of the carrier, and adjacent to the first magnet;
- a spring coupled to the carrier;

at least one second magnet disposed on one end of the carrier which is toward the holder;

a hall sensor for detecting a magnetic field of the at least one second magnet; and

a circuit board, wherein the hall sensor and an imaging element are connected to the circuit board, and the imaging element is for receiving an imaging light of the lens;

wherein the first magnet is an isosceles trapezoid-shaped cylinder, a bottom surface of the first magnet is adjacent to the coil, and two side surfaces of the first magnet are fixedly connected to the inner side of the cover;

wherein, a component parallel to an optical axis of the lens of a distance between the hall sensor and the second magnet which is detected by the Hall sensor is **d1**, a component orthogonal to the optical axis of the lens of the distance between the hall sensor and the second magnet is **d2**, and the following condition is satisfied:

$$d1>d2.$$

10. The lens driving apparatus of claim **9**, wherein a number of the second magnet is two, and the two second magnets are symmetrically disposed on the end of the carrier about the optical axis of the lens.

11. The lens driving apparatus of claim **9**, wherein the spring comprises:

a first spring member coupled to the other end of the carrier; and

a second spring member coupled to the end of the carrier which is toward the holder.

12. The lens driving apparatus of claim **11**, wherein the imaging element has 8 million pixels or above.

13. The lens driving apparatus of claim **11**, wherein the second spring member comprises:

a first portion; and

a second portion, wherein the first portion and the second portion are separated from each other and located on a same horizontal plane.

14. The lens driving apparatus of claim **11**, further comprising:

a spacer located between the cover and the first magnet, wherein the first spring member comprises:

at least one first fastening portion coupled to the spacer;

at least one second fastening portion coupled to the carrier; and

at least two elastic portions, each of the elastic portions connected to one end of the first fastening portion and one end of the second fastening portion, and for providing an elastic supporting force.

15. The lens driving apparatus of claim **14**, wherein the first fastening portion of the first spring member comprises at least two holes, and the second fastening portion of the first spring member comprises at least two holes.

16. The lens driving apparatus of claim **9**, wherein the coil is octagon.

17. The lens driving apparatus of claim **16**, wherein the component parallel to the optical axis of the lens of the distance between the hall sensor and the second magnet which is detected by the Hall sensor is d**1**, and the following condition is satisfied:

$$d1<1.4 \text{ mm}.$$

18. The lens driving apparatus of claim **17**, wherein the component parallel to the optical axis of the lens of the distance between the hall sensor and the second magnet which is detected by the Hall sensor is d**1**, and the following condition is satisfied:

$$d1<1.15 \text{ mm}.$$

19. The lens driving apparatus of claim **9**, wherein a side wall of the cover is closed-shape, one end of the cover is an opening end, the other end of the cover is an end wall which is connected to the side wall and has an opening hole.

20. The lens driving apparatus of claim **19**, wherein a number of the second magnet is two to six, and every two second magnets which are adjacent to each other are equidistantly disposed on the end of the carrier in a circumferential direction.

21. The lens driving apparatus of claim **20**, wherein a vertical distance between an outermost side of the end wall of the cover and a side wall of the hall sensor which is connected to the circuit board is H, and the following condition is satisfied:

$$3.4 \text{ mm}<H<5.8 \text{ mm}.$$

22. The lens driving apparatus of claim **20**, wherein a thickness parallel to the optical axis of the lens of the hall sensor is h, and the following condition is satisfied:

$$h<1.0 \text{ mm}.$$

23. The lens driving apparatus of claim **22**, wherein the thickness parallel to the optical axis of the lens of the hall sensor is h, and the following condition is satisfied:

$$h<0.6 \text{ mm}.$$

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